

**SHIP PRODUCTION COMMITTEE  
FACILITIES AND ENVIRONMENTAL EFFECTS  
SURFACE PREPARATION AND COATINGS  
DESIGN/PRODUCTION INTEGRATION  
HUMAN RESOURCE INNOVATION  
MARINE INDUSTRY STANDARDS  
WELDING  
INDUSTRIAL ENGINEERING  
EDUCATION AND TRAINING**

**September 1991  
NSRP 0340**

# **THE NATIONAL SHIPBUILDING RESEARCH PROGRAM**

**1991 Ship Production Symposium  
Proceedings:  
Paper No. VIA-3  
Improving Overhaul Planning  
Through Risk Assessment and Risk  
Management**

**U.S. DEPARTMENT OF THE NAVY  
CARDEROCK DIVISION,  
NAVAL SURFACE WARFARE CENTER**

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>SEP 1991</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>The National Shipbuilding Research Program, 1991 Ship Production Symposium Proceedings: Paper No. VIA-3: Improving Overhaul Planning Through Risk Assessment and Risk Management</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Naval Surface Warfare Center CD Code 2230-Design Integration Tools Bldg 192, Room 128 9500 MacArthur Blvd, Bethesda, MD 20817-5700</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>SAR</b>	18. NUMBER OF PAGES <b>16</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

## DISCLAIMER

These reports were prepared as an account of government-sponsored work. Neither the United States, nor the United States Navy, nor any person acting on behalf of the United States Navy (A) makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness or usefulness of the information contained in this report/manual, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or (B) assumes any liabilities with respect to the use of or for damages resulting from the use of any information, apparatus, method, or process disclosed in the report. As used in the above, "Persons acting on behalf of the United States Navy" includes any employee, contractor, or subcontractor to the contractor of the United States Navy to the extent that such employee, contractor, or subcontractor to the contractor prepares, handles, or distributes, or provides access to any information pursuant to his employment or contract or subcontract to the contractor with the United States Navy. ANY POSSIBLE IMPLIED WARRANTIES OF MERCHANTABILITY AND/OR FITNESS FOR PURPOSE ARE SPECIFICALLY DISCLAIMED.



THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS  
601 Pavonia Avenue, Jersey City, N.J. 07306

Paper presented at the 1991 Ship Production Symposium,  
The Pan Pacific Hotel, San Diego, California, September 3-6, 1991.

# Improving Overhaul Planning Through Risk Assessment and Risk Management

VIA-3

Robert G. Gorgone, Visitor, Philadelphia Naval Shipyard

## ABSTRACT

The execution of the overhaul of US. Naval vessels at a public shipyard is fraught with risk. Far too often the work authorization process is constrained by a limited budget. This situation can result in two common outcomes:

1. The shipyard delivers a ship to the customer that has significant repair work either deferred or incomplete; and

2. The deferred or incomplete work is screened back to the Shipyard late in the overhaul, forcing an upheaval in the logical planning and execution of the availability.

Risk affects both the shipyard and ship's force because the completion of the overhaul could be affected by late authorized work resulting in the ship not being able to meet her commitments.

As Philadelphia Naval Shipyard (PNSY) is an industry leader in zone or Group Technology execution methods, it is particularly disruptive to work flow to return to geographic areas and perform work in an area out of phase or even worse-in an area where similar work is already complete.

In the past the tools that were most often employed to build an effective work package, yet still remain within the budget, were personal experience, historical data and trends, and the necessary deletions of less critical work in favor of accomplishing essential repairs. The shipyard's success at making these determinations was held hostage by purely subjective opinions of the particular group of advance planners that attended the Work Definition Conference (WDC) and executed most of the advanced planning, without consideration of established overhaul objectives.

With the innovation of Zone Technology, it was clear that a consistent and effective risk assessment method must be developed to determine the probability of equipment failure during the testing phase of the overhaul and the impact on cost and schedule to the overhaul. The USS KIDD (DD-963)

scheduled availability in 1989 proved to be the ideal opportunity to develop and execute a formal risk assessment and management program. The USS CONSTELLATION (CV-64) SLEP availability in 1990 afforded the opportunity to refine and expand the risk assessment methodology.

## ACRONYMS AND DEFINITIONS

AAW: Anti Aircraft Warfare.

ALRE: Aircraft Launch and Recovery Equipment (Catapults, Arresting Gear, etc.)

APL: Allowance Parts List.

CASREP: Casualty Reporting System.

CNO: Chief of Naval Operations.

CSMP: Current Ships Maintenance Program.

ETC: Equipment Identification Code.

IEM: Inactive Equipment Maintenance.

LOE: Light Off Examination.

MCC: Mission Criticality Code.

NAVAIR: Naval Air Systems Command.

NAVSEA: Naval Sea Systems Command

NAVSES: Naval Ship Systems Engineering Station

NIU: New Threat Upgrade.

PEC: Predicted End Cost.

POT&I: Pre-Overhaul Test and Inspection.

RSR: Readiness Support Group.

SARP: Ship Alteration and Repair Package.

SIAT: Ship Installation Acceptance Test (Performed on Weapons Elevators).

SIMA: Ships Intermediate Maintenance Activity.

SPCC: Ships Parts Control Center.  
SLEP: Service Life Extension Program.  
T&C: Test and Certification.  
WDC: Work Definition Conference.

## INTRODUCTION

The success of an overhaul of a U.S. Navy ship depends on clearly defined overhaul objectives and a work package that supports these objectives. A work package consists of those repairs that are initially authorized, new items requiring repair identified during the overhaul, and growth which is an increase in the scope of repairs on a piece of equipment or system already being accomplished during the overhaul. Being able to accurately predict the end cost of an overhaul (i.e. projecting the amount of growth and new work to expect during the overhaul) is also a function of how well the total work package meets the overhaul objectives.

For a work package to satisfy the final objectives, these objectives must be strictly defined and a maintenance strategy clearly delineated. The maintenance manager must determine the truly necessary repairs and ensure those repairs are assigned to the groups with the capability and capacity to accomplish them within budget and schedule. Other less critical items must be identified and deferred for future availabilities or scheduled for accomplishment based upon schedule and shop loading. This action reduces the overall affect on cost and schedule by keeping introduction focus on the most critical jobs and at the same time helps to ensure a stable work force.

Shipyard risk on impacting cost and schedule of an overhaul is minimized by executing authorized work, ensuring overhaul objectives are met, and completing an availability on schedule. It is important that the proper repairs are authorized and consideration be given to reduce risk. Late identification of repairs based on testing can be avoided and problem areas identified through early diagnosis of cost and schedule drivers.

Risk assessment is not a new concept. Reliability and maintainability studies have been accomplished to determine mean time between failure of components in order to predict when that component should be overhauled. Most assessments take the maintenance manager's perspective and use risk analysis to assist in defining what needs an overhaul and ensure funds are not used to overhaul equipment unnecessarily. This paper assumes the perspective of the shipyard and provides a management tool that addresses the shipyard's in accomplishing late authorized work and provides a course of action that ensures the

work package is executable. Studies in the past used risk assessment to define the work, while availability of funds determined what actually was authorized. Funding constraints result in the shipyard assuming the risk of completing the authorized work on schedule, demonstrating those repairs, accomplishing system level testing and sea trials. It is during the testing phase when the greatest risk is revealed, generally resulting in late authorized work which, when using Zone Technology is accomplished out of sequence causing unnecessary delays and disruption as well as increased costs.

## OVERVIEW

Risk assessment was first used during the USS KIDD overhaul and subsequently used on the USS CONSTELLATION as a management tool to define the work to be accomplished. An overview of the USS KIDD and USS CONDITION overhauls are described as follows:

### USS KIDD Overhaul

The New Threat Upgrade (NTU) Program was initiated in the mid-seventies to improve the performance of the Anti-Aircraft Warfare (AAW) system on Navy cruisers. It was designed to improve the ability of the Terrier and Tartar ships to detect, track and engage antiship missiles. The NTU provides the ships with a modern AAW detection, tracking and target engagement system (1).

USS KIDD was the fourth ship to undergo the NTU overhaul. The work package was developed using traditional planning techniques including Pre-overhaul Test and Inspections (POT & I)'s. Current Ship's Maintenance Program (CSMP) and experience gained from the previous NTU availabilities. Nearly 54,000 mandays were identified for repairs. Funding constraints resulted in 23,206 mandays authorized at the Work Definition Conference (WDC). An additional 7,500 mandays were authorized after the Ship's Force WDC.

As a result of the funding constraints, the ship's force work package was significantly larger than in previous NTU availabilities. Much of their work was directed to a Shore Intermediate Maintenance Activity (SIMA). The Ship's force was provided a shipyard schedule which identified when their items and the SIMA items were required to be completed in order to support testing. When the ship arrived at the shipyard, work that was initially screened to ship's force and SIMA began to be re-screened to the shipyard because ship's force did not have the capability or capacity to accomplish all of their work. Recognizing potential problems, a risk assessment of the work not being accomplished by the shipyard was performed in order to develop contingency plans for executing late authorized work and

to accurately predict the end-cost of the availability. As previously stated, late authorized work is disruptive, impacts the schedule and is costly due to doing work out of sequence often resulting in rework. The basis of the risk assessment was to ensure that the Navy's overhaul completion criteria were met (2).

#### USS CONSTELLATION Overhaul

CV SLEP grew from an investigation in the mid-seventies initiated by Chief of Naval Operations, (CNO) Admiral Holloway, to determine alternatives to new construction for maintaining aircraft carrier force levels into the twenty first century.

Admiral Holloway's goal was to extend the service life of fossil fueled carriers by fifteen years, thereby ensuring their reliability for effective combat Operations with only routine maintenance through the extended service life. This goal was thought feasible through execution of an availability which stressed previously deferred structural and auxiliary system repairs along with replacement of equipment and systems for which logistics support is no longer attainable.

USS CONSTELLATION is the fifth Ship to undergo SLEP at the shipyard. The work package was developed using traditional planning techniques. A pre-authorized work package based on historical work authorization provided a baseline. Pre-overhaul Test and Inspections (POT & I) were conducted with extra emphasis placed on known problem areas and lessons learned from previous availabilities. This planning effort resulted in identifying nearly 1,400,000 mandays of known repairs and was based on overhaul objectives developed for previous SLEP availabilities.

The USS CONSTELLATION SLEP budget was reduced 35% by the US Congress. This reduction resulted in only 664,000 mandays authorized at the WDC as opposed to over 1 million mandays authorized at the WDC for the previous ships undergoing SLEP. The assignment of work at the WDC did not consider SLEP objectives and were based strictly on funding constraints. The result was a poorly defined overhaul for the ship with excessive work being accomplished by ship's force. The nature of the work differed from previous SLEPs in that several critical systems had responsibility split between ship's force and the shipyard.

Ship's force work also differed significantly from previous SLEPs. Ship's force was responsible for accomplishing more critical work than previously, requiring greater coordination with the shipyard's work, closer alignment with the Shipyard's schedule and greater involvement in the test and certification program. In order to ensure that an executable overhaul was

authorized, a risk assessment was conducted on the following areas as of concern:

1. Work not screened to the shipyard:
2. Work screened to the shipyard but partially funded and:
3. Work that was screened to the shipyard and fully funded.

#### **METHODOLOGY**

It was necessary to develop a method to quantify risk, taking into consideration the capability and capacity of the overhauling agent and ensuring the customers objectives would be met. The risk assessment procedure developed for USS KIDD as described below and was based on ranking the work using basic risk categories.

The approach used for conducting the USS KIDD risk assessment was reviewed for use on USS CONSTELLATION. The difference in size, complexity, and duration of the two availabilities required expanding the assessment technique. Consideration had to be given to intermediate milestones, an expanded test and certification program and to Ship's force work. The fact that no formal objectives existed for USS CONSTELLATION also factor in determining the procedure utilized.

#### USS ASSESSMENT PROCEDURES

The work package review and risk analysis for USS KIDD considered the work assigned to Ship's Force, SIMA Headiness Support Group (RSG), Naval Ship Systems Engineering Station (NAVSES): as well, as deferred items. The work was reviewed with Particular attention to those equipments and systems of which potential failure of a particular piece of equipment could result in new work being assigned to the Shipyard late in the availability. Testing and schedule risks were also assessed. This assessment was accomplished by the project manager who had the greatest experience and knowledge of USS KIDD's planning and work package.

The assessment criteria for each item included the following:

1. Listing of repair items that were the responsibility of ship's force:
2. Ship's force generated deficiency report that identified known work:
3. Light Off Examination/Test Critical (Yes or No) :
4. Ship Mission Critical (Yes or No)-(based on known overhaul objectives):
5. Risk of Failing during testing (Low, Medium or High

6. Test Impact Risk (Low Medium or High) and:

7. Schedule Impact Risk (Low, Medium or High).

The three risk categories (Failure. Test and Schedule) were assigned the following values by the project manager while considering the overhaul objectives:

1. .50 for new work that is considered High Risk.
2. .40 for new work that is considered Medium Risk, and
3. .10 for new work that is considered Low Risk.

A cumulative risk was calculated by summing the High, Medium or Low risk values for each item resulting in a weight factor less than 1.0. The weight factor multiplied by the estimated cost measured in mandays resulted in the weighted mandays or growth reserve anticipated.

The sum of the weighted mandays or growth reserve. when added to the current sales estimate provided the Predicted End cost (PEC) for the overhaul. The PEC was monitored and tracked throughout the overhaul.

The risk assessment provided data that allowed shipyard managers to submit two fixed price offers for USS KIDD. The first fixed price offer used traditional procedures for predicting the end cost of each item being repaired based on physical progress of that item. The second but higher fixed price offer, took into consideration the risk assessment as well as the data used for the first fixed price. This was calculated by adding the weighted mandays from the risk assessment to the predicted end cost of all the work being accomplished during the overhaul. The higher fixed price offer was based on the shipyard assuming the risk for all-new work and/or growth and assuming that no catastrophic failures outside the normal scope of overhaul work would occur.

The lower offer. without the risk assessment being considered, was accepted. The shipyard continued to monitor the high risk items and track the costs for additional work anticipated to be authorized in accomplishing the high risk items. Contingency plans were made by reviewing material availability. ordering the most critical long lead time items and ensuring documentation was available for accomplishing repairs on those items categorized as high risk. The contingency planning was done to lessen the impact when and if the high risk items were authorized for shipyard accomplishment.

#### USS CONSTELLATION RISK ASSESSMENT PROCEDURES

The process used for risk assessment on USS KIDD was based on a relatively small work package. The size and complexity of USS CONSTELLATION'S overhaul required establishment of a detailed step by step procedure.

Resources used to conduct the risk analysis for the USS CONSTELLATION included shipyard personnel. primarily from the SLEP Project Office. Combat Systems and the Hull propulsion and Auxiliary Test Branch. U.S. Navy from the Type Commander Staff experts were used where specific fleet experience was required and specialists were called in for combat systems. aircraft launch and recovery and main propulsion. The outside resources served two functions, providing an independent analysis that reviewed and validated shipyard data and augmented organic resources with fleet experience.

The risk assessment was based on two factors as described by Bertrum Smith. Jr. (3):

1. Probability of equipment Failure
2. Consequences of equipment Failure

Probability of failure takes into consideration a maintenance burden factor, or how often something fails. This portion of the analysis was purely objective because the source of information was a report from the Naval Sea Logistics Center titled "Logistics High Failure Equipment" (4). This report lists the top 300 equipment by Equipment Identification Code (EIC) for each ship. A numerical value was assigned based on where that piece of equipment was in the top 300 listing. It should be noted that the report covered only Naval Sea Systems Command (NAVSEA) cognizant equipment. Naval Air systems command (NAVAIR) cognizant equipment was assigned scores by knowledgeable personnel assigned to the risk assessment team who had been thoroughly briefed on the concepts involved.

Consequences of failure were based on mission impact and availability impact. The sources of data included mission criticality studies for other classes of ships and the matrix and logic tree shown in Figure (1). This portion of the analysis was also objective and tailored the results to be consistent with the Navy's Casualty Reporting (CASREP) system.

The risk impact on the availability was determined using the following criteria:

1. Impact on the Shipyard
  - a. Test/Certification
  - b. Schedule Events (7)

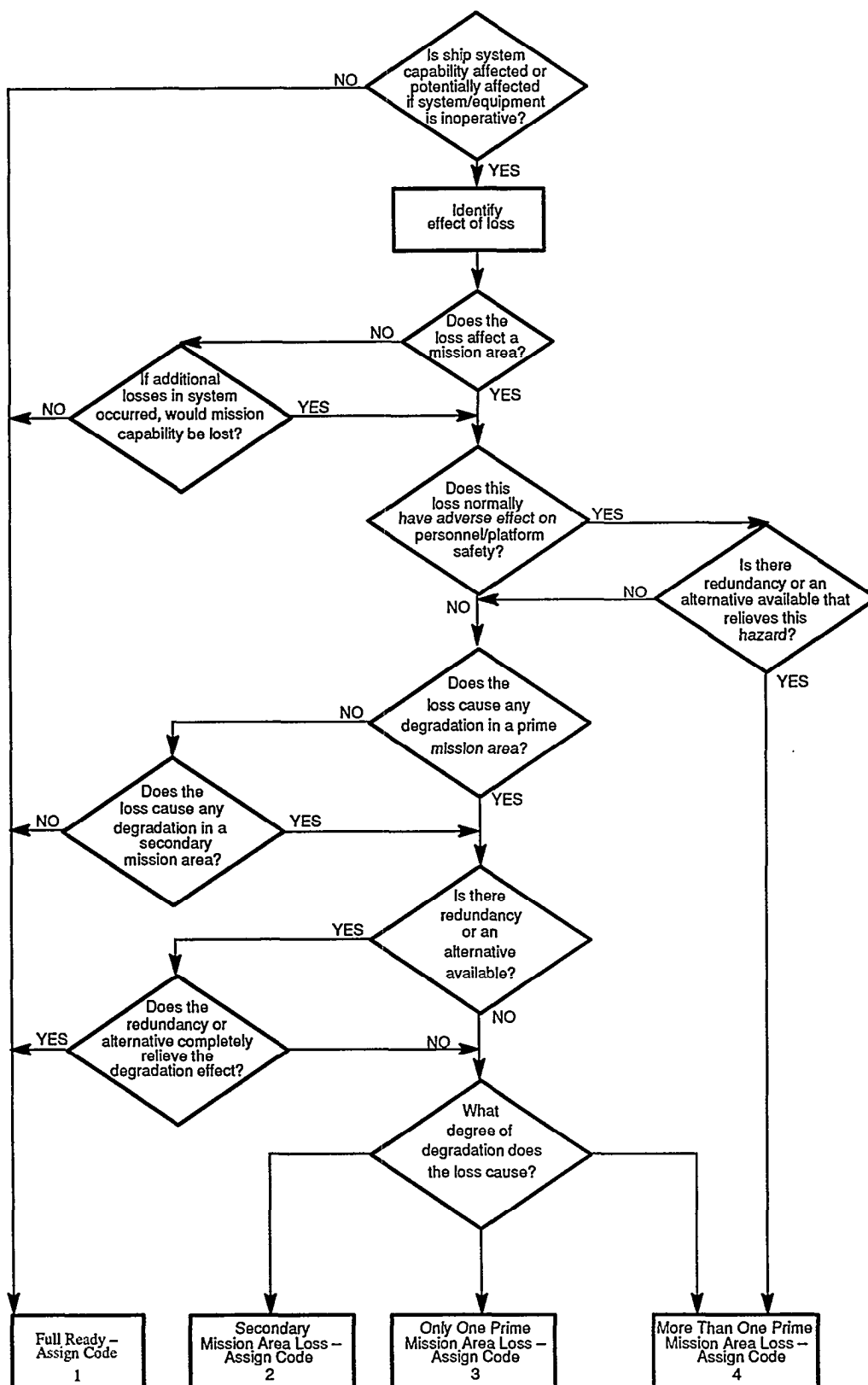


Figure 1  
Mission Criticality Decision Logic Tree



- a. Impact on Ship's Force
  - a. Capability
  - b. Workload

Schedule impact included impact on major events such as undocking, Light Off Exams (LOE'S), Ship Installation Acceptability Tests (STAT), Aircraft Launch and Recovery Equipment (AIRE) certification. crew move aboard. complete availability, etc. Impact on ship's force also considered work screened to various intermediate maintenance activities.

The U.S. Navy's contract to a Shipyard for a ship under overhaul known as the Proposed Ship Alteration and Repair Package (SARP) (Prepared by the Shipyard in June 1989 for WDC Use) was divided into four categories as listed below and used in the analysis:

1. Category I: Work not authorized to the shipyard:
2. Category II: Work authorized to the shipyard but only partially funded:
3. Category III: Work authorized the Shipyard and fully funded:
4. Category IV: Modernization items or Ship Alterations.

Category I included all work authorized to the ship's force. SIMA and not authorized/deferred. Category II and III were determined by taking the mathematical average for similar work from previous SLEP availabilities. If the **CONSTELLATION** estimate was 79% or less than the average. it was placed in Category II: if it was 80% or greater in Category III. This process was followed for each line item in the SARP in each of the four categories.

The work sheet utilized is shown in Figure 2. The basic information was extracted from the USS **CONSTELLATION** computerized SARP data base.

#### **RANKING THE RESULTS**

Values from 1 to 5 (1 being least likely to impact the overhaul schedule if repairs were identified late. 5 being most likely to impact the overhaul schedule) were assigned to each of the parameters discussed later in this paper with the exception of Mission Criticality which had a maximum score of 4.

Adding the scores for each parameter, and dividing by 29 (the maximum possible score) resulted in a calculated weighting factor which did not exceed 1.0. Historical data was used to determine cost estimates where actual estimates did not exist. Estimates were multiplied by the weighting factor to obtain weighted costs.

#### **PROBABILITY OF FAILURE**

The Naval Sea Logistics Center publishes a report that sequentially ranks all reported equipment and displays the pieces of equipment that fail or break down and requires overhaul most frequently. Eight maintenance generated factors are quantified and ranked to determine a composite rank of each piece of equipment. These eight factors are weighted equally for the standard report. For each listed piece of equipment. as many as eleven Allowance Parts List (APL) Numbers/Equipment Identification Codes (EIC) are ranked. displaying nomenclature and percentage of repair actions to total times the piece of equipment requires overhaul. APLS/EICS are indexed on the final page of the report. Report option 03: EIC-All reported Data Option and 04: APL-ALL reported data for the USS **CONSTELLATION** for the Reporting Period June 1984 through February 1989 were received from the Naval Sea Logistics Center. The EIC (Option 03) was selected and used for ease of referencing to the system work breakdown structure.

Weighting Factor Scores were assigned in accordance with Table I where the highest ranking means that piece of equipment is more likely to fail.

Report Ranking	Score
1-50	5
51-100	4
101-150	3
151-200	2
201-ONWARD	1

TABLE I

#### **CONSEQUENCES OF FAILURE**

The Consequence(s) of Failure were divided into two areas: impact on ship's mission and impact on the overhaul completion.

#### Mission Related Impacts

The Navy Ship Parts Control Center (SPCC) in Mechanicsburg. PA. Provides a list of Mission Criticality Codes (MCCs) . a numeric code assigned to a system. equipment. or component in a specific application to denote its importance to the mission assignment of the military unit in which it is installed. MCCs consist of a numeric code of 1 through 4 to designate the importance of the system. equipment or component with 4 indicating the most significant and 1. the least. MCCs 1 through 4 correlate directly to Casualty Reporting (CASREP) codes severity (MCC 4 equivalent to C4 severity). Since operational alternatives and redundancies can reduce CASREP severity,

CONSTELLATION (CV-64) RISK ANALYSIS AND MANAGEMENT														
CATEGORY 3: SHIPYARD FULLY-FUNDED ITEMS														
BY SWLIN BY WORK PROCEDURE														
DATE: 08/30/89														
PAGE: 1														
SWLIN	WORK PROC	SCRM	M S	DESCRIPTION	LEVEL IMPACT	PROB FAIL	MISSION IMPACT	OVERHAUL IMPACT		--S/Y--- --S/F---		WGHT FACT	MANDAY ESTIMATE	WEIGHTED MANDAY ESTIMATE
-----														
22111	002.01	SY	3	BURNERS:	C	5	3	3	3	1	3	0.621	293	182
22111	002.02	SY	3	A. MANUFACTURE & TEST	C	5	1	3	2	5	1	0.586	46	27
22111	003.01	SY	3	CASING REPAIRS:	C	5	3	3	2	5	1	0.655	2082	1364
22111	004.01	SY	3	DRUM INTERNALS:	B	5	3	4	4	3	5	0.828	307	254
22111	005.01	SY	3	BOILER INDICATORS:	C	1	1	5	3	1	1	0.414	173	72
22111	006.01	SY	3	BOILER TESTS:	B	5	1	5	4	1	1	0.586	373	219
22111	007.01	SY	3	SUPERHEATERS:	A391	5	3	4	5	5	3	0.862	2436	2100
22111	008.01	SY	3	SOOT BLOWERS:	B	5	1	3	4	3	3	0.655	244	160
22111	009.01	SY	3	BOILER FOUNDATIONS & S	C	5	1	3	3	5	1	0.621	445	276
22111	011.01	SY	3	PRESSURE PARTS:	B	5	3	5	4	3	5	0.862	328	283
22111	012.01	SY	3	BOILER S.O.I. - (NAVSS	A391	5	1	1	5	5	1	0.621	390	242
22111	013.01	SY	3	REFRACTORY:	B	5	3	3	4	3	3	0.724	801	580
22111	014.01	SY	3	SAFETY VALVES:	A391	5	3	5	5	1	3	0.759	300	228
22111	016.01	SY	3	BOILER ISOLATION VALVE	B	5	3	5	4	1	3	0.724	331	240
22111	017.01	SY	3	WATERSIDE MAINTENANCE:	C	5	1	1	2	1	3	0.448	369	165
22111	018.01	SY	3	BOILER DESUPHTR ASSEMB	C	5	3	4	3	1	3	0.655	654	428
22111	019.01	SY	3	SIDEWALL & REARWALL RE	C	5	3	3	3	3	3	0.690	84	58

Figure 2  
Impact Assessment Worksheet

this correlation is also applicable to MCC assignments. when identical systems. equipment or components are installed in a single military unit and support different missions, the highest MCC was applied. The MCC was assigned from the matrix in TABLE II.

Because an explicit MCC study does not exist for the USS CONSTELLATION, the Mission Criticality Decision Logic Tree shown in Figure 1 was utilized to define the MCC when appropriate. Additionally, the "Aircraft Carrier Material Condition and Readiness Study Report" (5) was utilized in conjunction with "Summary of Propulsion Auxiliary Machinery in Operation" extracted from the Operating Guide for Propulsion Machinery (6) to more clearly define the impact on the ship's ability to perform its primary mission. The Summary of Propulsion Auxiliary Machinery in Operation is included as Figure 3.

Structural repairs were evaluated by locating the work site on the ship's plans and assessing the impact on mission performance. For example, machinery space longitudinals were believed to have a high level of redundancy. be unlikely to fail suddenly and would therefore have a low MCC. Conversely, serious catapult trough deterioration could result in track cover. cylinder or water-brake misalignment and could therefore have a significantly higher KC.

Structural repair impact on ship certification and schedule events was evaluated at the same time. To use the previous example, machinery space longitudinals would not have any significant impact on T & C or on the schedule, whereas a deteriorated ladder in an escape trunk would likely result in a restrictive discrepancy. Much of the heavy structural work was assessed as beyond the capability of ship's force and as a significant workload burden for ship's force despite the low MCC. T & C. and schedule impacts.

#### Overhaul completion Related/Impacts

This category was divided into four segments.

The following table is an analysis of the impact on a Test or Certification if the item were to fail.

#### Shipyard Schedule Impact

The shipyard utilizes Zone Technology and Event Management (7) as the process to focus management attention on segments of an overhaul above key operation level that are large enough to be significant. small enough to be managed and of the substance to provide frequent clear progress markers without obscuring the issues. The scheduling system is based on a hierarchical

# **ALTERNATIVES FOR MISSION ACCOMPLISHMENT**

# **IMPACT IF ALTERNATIVES FAIL**

Redundant  
systems/  
equipments/  
components  
available

Alternatives Neither  
[excluding redundancies  
redundancies) nor other  
available alternatives  
available

3	4	4	Total loss of mobility (propulsion or life support).
2	3	4	Severe degradation of mobility. total loss of a primary mission.
1	2	3	Severe degradation of a primary mission
1	1	2	Total loss or severe degradation of a secondary mission.
	1	1	Minor mission impact.

## **MISSION CRITICALITY CODES**

TABLE II

	SPEED SHAFT REVOLUTIONS	AHR 0	15 K 74	20 K 100	25 K 126	30 K 153	Full Power 170	*20% BLR Overload 140 (est)	Full Power Astern 82
# On SHIP	IDENTIFICATION								
4	Main Turbines in Use	0	4	4	4	4	4	4	4
4-M, 4-T	Main Condensate Pump	0	4-T	4-T	4-T	4-M, 4-T	4-M, 4-T	4-T	4-T
4-T	Main Circulating Pump	0	0	0	0	0	0	0	0
4	Main Air Ejectors	0	4	4	4	4	4	4	4
4-M, 4-T	Lube Oil Service Pump	0	4-T**	4-T**	4-T**	4-T**	4-T**	4-T**	4-T
4-M	Emer Lube Oil Service Pump	0	0	0	0	0	0	0	0
4	Attached Lub Oil Pump	0	4	4	4	4	4	4	4
4	Lube Oil Cooler	0	4	4	4	4	4	4	4
4	Gland Exhaust Fan	0	4	4	4	4	4	4	4
8	Boilers in Use	2	4*	4*	8	8	8	4*	8
12-T	Main Feed Pump	2-T	4-T	4-T	8-T	8-T	8-T	4-T	8-T
4-M, 8-T	Main Feed Booster Pump	2-M	4-T	4-T	4-M, 4-T	4-M, 4-T	2-M, 2-T	2-M, 2-T	4-M, 4-T
4-M	Emer Feed Booster and Reserve Transfer Pump		ASRQ	ASRQ	ASRQ	ASRQ	ASRQ	ASRQ	ASRQ
4	Deaerating Feed Tank	1	4	4	4	4	4	4	4
24-T	Forced Draft Blower	2-T	4-T	8-T	16-T	24-T	24-T	12-T	8-T
12-T	Fuel Oil Service Pump	0	4-T	4-T	8-T	8-T	8-T	4-T	8-T
4-M	Port Use FO Service Pump	2-M	0	0	0	0	0	0	0
8	Control Air Compressor	2	4	4	8	8	8	4	8
8	Turbo Generators In Use	2	6	6	6	8	8	8	8
8-M	Auxiliary Condensate Pump	2-M	6-M	6-M	6-M	8-M	8-M	8-M	8-M
8-M	Auxiliary Circulating Pump	2-M	6-M	6-M	6-M	8-M	8-M	8-M	8-M
8	Auxiliary Air Ejectors	2	6	6	6	8	8	8	8

It should be noted that all ratings are based on Equal Shaft Revolution, and these ratings will vary if shaft speeds are split, these values will also change in accordance with Catapults in use.

M = MOTOR DRIVEN

T = TURBINE DRIVEN

ASRQ = AS REQUIRED

\*\* = IDLING

\* = 4 BOILER OPERATION, 2 IN EACH OF 2 MACHINERY SPACES, CROSS-CONNECTED PLANT

**Figure 3**  
**Summary of Propulsion Auxiliary Machinery in Operation**

<b>CATEGORY</b>	<b>DEFINITION</b>	<b>SCORE</b>
Major Impact	High probability of failing a major certification requirement (LOE, SIAT, ALRE etc.)	5
Significant Impact	Moderate probability of equipment/system failing a major certification. but one or more schedule "work arounds" exist.	4
Moderate Impact	Low probability of failing a major certification/moderate probability of failing a minor test or certification: schedule "float" exists.	3
Some Impact	Low probability exists of failing a minor test or certification. Corrective action can be accomplished in a short time without schedule impact.	2
Low Impact/ No Impact	No discernable probability of impact on any test or certification	1

#### **SHIPYARD TEST & CERTIFICATION IMPACT**

TABLE III

arrangement of events and a weekly monitoring of those events. The following definitions are provided:

A-Event or Key Event:  
the highest level of events. A key event date cannot slip without seriously impacting the overall schedule.

B-Event or Milestone Event:  
normally within the controlling oaths leading to key events.

C-Event or Schedule Event:  
normally used to maintain momentum on a project by focusing management attention on completion of near term events.

The analysis is of the impact to the overhaul schedule if a piece of equipment or system were to fail during an overhaul is shown in Table IV.

<b>CATEGORY</b>	<b>DEFINITION</b>	<b>SCORE</b>
Major Impact	High probability of impacting an "A" level event.	5
Significant Impact	High probability of impacting a "B" level event, significant probability of impacting an "A" level event.	4
Moderate Impact	High probability of impacting a "C" level event. significant probability of impacting a "B" level event.	3
some Impact	Impact confined to <i>job</i> order level only	2
Low Impact/ No Impact	Impact confined to key operation level only	1

#### **SHIPYARD SCHEDULE IMPACT**

TABLE IV

#### Ship's Force Capability Impact Items

An analysis that measures whether the ship's force has the requisite skills to accomplish the assigned task is shown in Table V.

After a full set of data was entered for any given line item, a Weight Factor (WF) was calculated by summing the scores for probability of failure, mission impact, test and certification impact, schedule impact, ship's force capability and ship's force workload burden. This sum was divided by the

#### IMPACT ON SHIP'S FORCE- CAPABILITY

CATEGORY	DEFINITION	SCORE
Major Impact-	Beyond Ship's Force capability due to skills or equipment required	5
Moderate Impact	Ship's Force can do portions of job - "Assist Ships Force" (ASF) dollars required	3
Low Impact/ No Impact	Ships force can do without help	1

#### IMPACT ON SHIP'S FORCE - CAPABILITY

TABLE V

#### Ship's Force Workload Burden Impact Items

A measure in dollars in term of ship's force level of effort if the item were identified late in the availability. These repair items would also impact the shipyard unless ship's force were to redirect their assests based on historical ship's force work packages.

maximum possible value of (29), yielding a WE' less than 1.0.

#### CALCULATION OF WEIGHTING MANDAYS

Cost estimates (measured in mandays to accomplish the work) were obtained from

#### SHIP'S FORCE WORKLOAD BURDEN

CATEGORY	DEFINITION	SCORE
Significant Burden	Requires a major re-direction of Ship's Force assets. May have an impact on the Shipyard unless contractual alternatives exist. (An example would be providing firewatches which is accomplished by ship's force. If ship's force were not available to do firewatch services. this effort would require contractor support).	5
Moderate Burden	Some elements of Ships Force work will be deferred until after completion. (Painting/Tiling)	3
Low/None	Very minor job, no discernable impact	1

#### SHIP'S FORCE WORKLOAD BURDEN

TABLE VI

#### CALCULATION OF WEIGHTING FACTOR

The study was accomplished in phases by category. Points were assigned for each repair item at the SARP line item level. Data entry was performed at a variety of personal computers which allowed incremental data input.

either the Proposed SARP for USS CONSTELLATION, historical information contained in the current SARP for USS KITTY HAWK (CV63) SLEP or the COMPLETION SARP for USS INDEPENDANCE (CV-62) SLEP for similar work. The "Weighted Mandays" were calculated by multiplying the estimated costs by the

maximum Possible value of (29). Yielding a WF less than 1.0.

#### CALCULATION OF WEIGHTING MANDAYS

Cost estimates (measured in mandays to accomplish the work) were obtained from either the Proposed SARP for USS CONSTELLATION. historical information contained in the current SARP for USS KITTY HAWK (CV63) SLEP or the completion SARP for USS INDEPENDANCE (CV-62) SLEP for similar work. The 'Weighted Mandays' were calculated by multiplying the estimated costs by the Weighted Factor". The results were entered in the column titled Weighted Manday Estimate'. Weighted mandays for Category II High Risk items were calculated by subtracting the authorized mandays from the estimate to fully fund the item and multiplying this value by the Weighted Factor".

#### ESTABLISHING RISK LEVELS

High risk was defined for both mission impact and overhaul impact. For mission impact, high risk was defined as any line item in the SARP having a Mission Impact score greater than 3. This means the risk "threshold" was set below those items which result in mission degrading casualties.

High risk for overhaul impact was defined as any line item having an overhaul impact score greater than 14. Individual parameter "thresholds" were set as:

1. Test & Certification is greater than 4;
2. Schedule is greater than 4;
3. Shin Force Capability is greater than 3; and
4. Shin Force Workload Burden is greater than 3.

Scores greater than 14 defined items which have "High Risk" and therefore need additional consideration for authorization.

At this point it should be noted that a "hysteresis-like" phenomenon exists between the processes of reducing risk by "adding" work to and increasing risk by "subtracting" work from the work package described in the SARP. This phenomenon may be displayed graphically as shown in Figure 4.

For this study, the difference in level of risk between "High" and "Acceptable" was determined by the set of conditions defined above, and those for "Acceptable Risk" which are as follows:

1. Test & Certification less than 2:

2. Schedule less than 1:

3. Shin's force Capability less than 1:

4. Shin's force workload burden less than 1.

This indicates that weighting factor scores less than 5 define line items which have "Acceptable Risk." and are therefore candidates for deletion from the work package to permit the funds associated with them to be utilized in the authorization of high risk line items.

#### RANKING THE RESULTS

Several reports were generated in order to analyse the data that was collected and rank the results. The calculated Weighted Mandays" were ranked in three ways as follows:

A. By magnitude of weighted mandays.

B. By mission impact. and

C. By overhaul completion impact

This allowed the data to be reviewed and an analysis to determine what was an acceptable risk.

#### USS KIDD Risk Results

4,875 high risk weighted mandays were identified. These items included stern tube seals, lube oil flushes, main lube oil pumps, fire pumps, salt water service pumps, etc. A total of 4,475 mandays were ultimately authorized as additional work for the shipyard on USS KIDD late in the overhaul.

#### USS CONSTELLATION Risk Results

There were 8,859 line item in the USS CONSTELLATION'S SARP. After the rating and ranking process and the application of "High Risk" criterion previously discussed, the number of line items which required close study. Possible re-assigning to the shipyard and/or additional funding was reduced to 1,172. These items were from both Category I as defined in the USS CONSTELLATION risk assessment Procedure (594 line items not screened to shipyard) and Category II (578 line items not fully funded). This meant that parties to the WDC, including the shipyard, NAVSEA, and shin's force could concentrate their efforts on 13.2 percent of the total line item.. rather than the entire package. for determining changes. The reports because an integral part of the decision making process with frequent references made throughout the WDC.

The availability of mandays associated

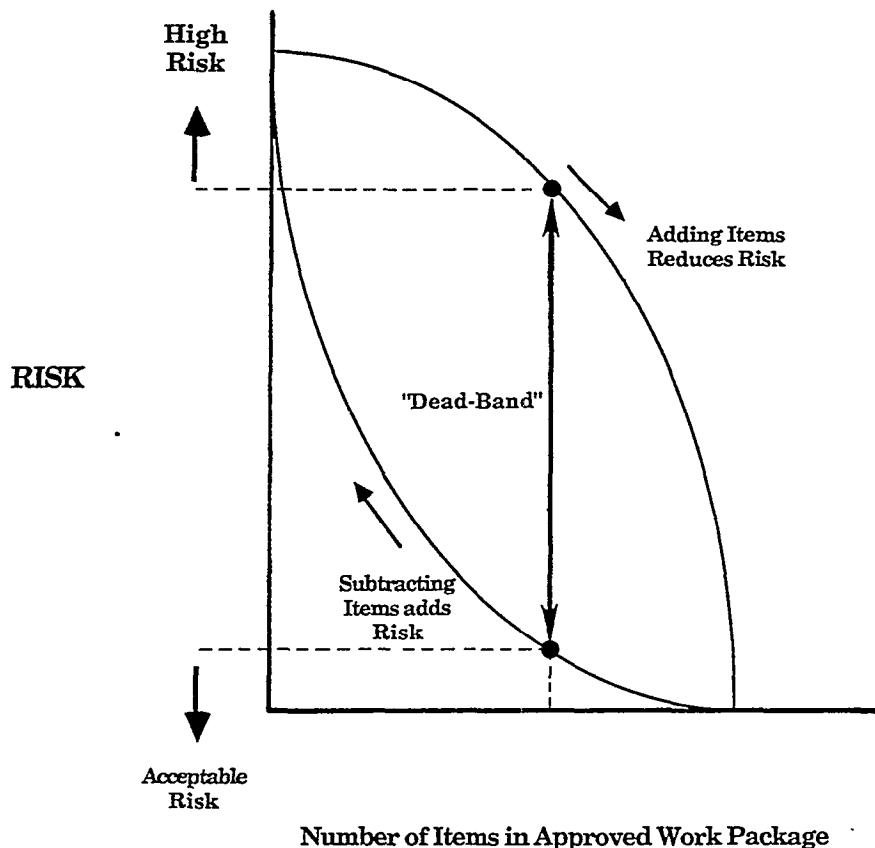


Figure 4  
Risk Level Hysteresis Effect

with Category III (those repairs being accomplished by the shipyard line items with an overhaul impact is less than 5. mitigates. but does not eliminate, the risk associated with the 1,172 line items in Categories I and II. Additional trade-offs were required.

The risk assessment was undated to reflect decisions from the WDC. The 1,172 High Risk items were reviewed and reduced to a 337 line item list for further consideration (313 Category I and 24 Category II). This candidate list represents 113.292 mandays of growth reserve from Category I and 28.433 mandays of growth reserve from Category II which, based on the experiences on USS KIDD, can be anticipated. The anticipated growth reserve for both USS KIDD and USS CONSTELLATION represents 21 percent of the work authorized at the WDC. category III Acceptable Disk Candidates. of which their are 128, represents 3,543 mandays of work that could be deferred.

Specific actions taken on USS CONSTELLATION. The High Risk candidates list was reviewed to identify additional operational tests or detailed inspections to be conducted prior to the USS

CONSTELLATIONS arrival. Those items not rescreened to the shipyard required specific lay-up procedures and detailed Inactive Equipment Maintenance (IEM) instructions to detailed inspections to be conducted prior to the USS CONSTELLATION'S arrival. Those items not reassigned to the shipyard required specific lay-up procedures and detailed Inactive Equipment Maintenance (IEM) instructions to ensure no degradation occurred as a result of the industrial environment and length of the availability. Lavup and IEM for these items were Ship's Force reponsibility.

Second. those items for which operational testing was not feasible were reviewed jointly between NAVSEA and the shipyard for reconsideration and to eliminate potential problems in execution of the work.

Finally, the Category I and Category II High Risk mandays (141.725 mandavs) were used in calculating the Predicted End Cost of the availability.

## CONCLUSIONS

The USS CONSTELLATION overhauling is fifty percent complete. To date over 20.00 mandays of high risk items have been reassigned to the shipyard. The ranking procedure for risk assessment continues to be used throughout the USS CONSTELLATION overhaul. for all new work requests. Work is accepted or rejected by the Shipyard based on the risk assessment criteria. This includes requests for Design investigations and Planners estimates. Those items not considered to be "High Risk" will be returned to the customer thus conserving Design and Planner resources. The ranking procedure is also used by the customer to prioritize the authorization of new work.

The risk assessment will be accomplished on all future assigned availabilities in order to assess the executability of the overhaul. to define which equipments should be overhauled and to determine the predicted end cost. The results will be monitored and work authorization measured against the risk assessment results.

The techniques used on USS CONSTELLATION provide a disciplined approach for the shipyard towards work package development and defining what repairs should be accomplished. It allows a reassessment of work package priorities and provides a level of confidence in meeting overhaul objectives. An analysis of this type also exposes the shipyard to a greater depth of knowledge and to the potential problems of the work package prior to the start of the availability.

1. Goodman. Glenn W. "New Threat Upgrade Modernizes AAW Capabilities of Pre-Aegis Ship's". Armed Force Journal International, April 1987. pg. 91.

2. "Overhaul Completion Criteria For Atlantic Fleet Ships" CINCLANTFLT Norfolk VA 2615562 OCT 85.

3. Smith. Bertrum. Jr. "Risk Management in Repair Work Decision Making". Naval Engineers Journal. May 1989 pg. 220-230.

4. Naval Sea Logistics Center. Mechanicsburg. Pa.. 3M Report 4790.5711.

5. NAVSEADDET PERA cv. "Aircraft Carrier Material Condition and Readiness study Report"

6. "operating Guide for propulsion Machinery". Naval Sea System command: POG. S9CVA-64-POG-010..

7. "Shipyard Requirements for Event Management" Philadelphia Naval Shipyard Instruction 4850.23A. 30 November 1988.



Additional copies of this report can be obtained from the  
National Shipbuilding Research and Documentation Center:

**<http://www.nsnet.com/docctr/>**

Documentation Center  
The University of Michigan  
Transportation Research Institute  
Marine Systems Division  
2901 Baxter Road  
Ann Arbor, MI 48109-2150

Phone: 734-763-2465  
Fax: 734-936-1081  
E-mail: [Doc.Center@umich.edu](mailto:Doc.Center@umich.edu)